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PULVERISED OIL PALM WOOD (*ELAEIS GUINEENSIS)* IN CLAY BODY AND CERAMIC WEIGHT AFTER FIRING

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Abstract

Pulverized Oil Palm Wood (Elaeis Guineensis) as an additive to clay body and the effects on the ceramic body after firing is considered in this study, because of the benefit it would bring about in the ceramic product. The experiment was conducted so as to determine whether the effects would be significant enough ($\pm$0.05) to be recommended for usage in ceramic products. The method of conducting the experiment involved the analysising of the pulverized oil palm wood, blending it with an adopted claybody, in different ratios and subjecting them to firing temperature ranges from 650^{0}C – 1050^{0}C oxidation atmosphere. The firing was then augmented with liquefied gas to 1230^{0}C still in oxidation atmosphere. Mean Standard Deviation was used to test the research questions and independent t-test was used to analysed the data collected in the experiment. Results showed that the difference in weight depended on the ratios of the composed POPW in claybody and the ranges of temperature passed through. The reduction in weight from the additive is recommended for making ceramic objects that need light weight in industries.

Keywords: *Pulverized Oil Palm Wood (POPW), Wood In Clay, Weight, Ceramic Firing.*

Introduction: Ceramics is an age-long profession, a cultural craft practice that is constantly evolving, using clay as a principal raw material to manipulate into shapes, sizes and forms ending finally as fired products. It is believed to have started independently in many parts of the world in response to the needs of the local potters (Lious, 1978:1254). According to Igwilo (2006:194 – 205) "ceramic as a word originated from the Greek word 'keramos', meaning subjected to, or hardened by fire".

Ceramics therefore involve, “all objects made in clay with or without other materials rendered permanent by heat through firing (Umar, 2006)”. Ceramists like Rhodes (1968:101), Cardew (1971:145), Zakin (1990:18), Grahl (2004:27), Oke and Udom (2007:101) have confirmed that when clay, hydrated aluminium silicate ($Al_2O_3.2SiO_2.2H_2O$), is used to form any object and is fired to vitrification, it cannot return to clay again. This object becomes a ceramic or fired clay design made by a potter or ceramist. The activity of the craftsman is therefore classified as the study of ceramics. According to Ojie and Esosuakpor (2008:76), a clay body becomes less porous as fusion occurs because of the temperature increases. During fusion therefore great heat is absorbed by the wares to enable the elements in the clay to vitrify.

Podmore (1980:15) posited that it is only at a temperature of more than 1000^oC that heat can be absorbed enough, for mullites and cristobalites formation. The interplay of alumina and silicate structures to produce fusion can only occur during heat interaction (Sulton,2011:22). This means that changing a clay body to ceramic involves heat absorption (Essien, 1997;120). In order to explain the complexity of the reality in the true contents of the clay material, Essien (1997:120) posited that the annotated clay formula is not as clean as $Al_2O_3.2SiO_2.2H_2O$, but has impurities X added as prefix that is, X. $Al_2O_3.2SiO_2.2H_2O$. The “X” is explained here as different elements in the alkaline group and the carbon, with their different melting temperatures. These elements though in small amount assist clay as fluxes (softeners) during fusion in firing (Zakin, 1990:9). Peters (2000:121) ,and(Sulton,2011wwwactivemineral.com) pointed to the historical background of ceramic as the product of earth, water and fire. Clark (1968:6) enunciated that the success of ceramics through the ages and future would depend on manipulation of earthy materials with water and efficient firing. Clark (1968:6) and Peter (2000:121 – 123) further agreed that ceramics materials are processed and manipulated to create other new products which affect new usage

Renowned ceramics scholars like Rhodes (1968:70), Cardew (1971:145), Zakin (1990:11-38), Speight and Toki (2004:183) have pointed with interest to the presence of a lot of organic materials in clay, from plants and animals that exist together in the clay environment. The postulation is that organic matter becomes useful either for fermentation or as a source of fuel during firing (Zakin, 1990:33). Over the years, these sources of fuel (organic material in clay) together with other newly found energy sources have been and will continue to be employed for ceramic firing in different cultures (Clark, 1968:4; Speight and Toki,2004:183). This implies that the search for fuel sources is continuous. The contemporary sources include oil, electricity, gas, kerosene and wood (Rhodes, 1968:98). It is observed that where oil or kerosene is utilised, it is complex, more expensive and more subjected to mechanical failure as there is need to vaporise them so as to reach their respective ignition points for combustion to occur.

Where wood is used, in the traditional method of wood on clay, a lot of space is unnecessarily taken up because of the volume of wood. In a kiln where the volume of the kiln is constant, it becomes desirable not to fill in too much wood so as to allow more space for ceramic wares in the kiln. Rhodes (1968:63) recommended that wood firing however is not as troublesome, difficult or expensive as one may think.

From the foregoing, there is a necessity to look at the concept of suitability of wood in terms of method of application and the effect on ceramic weight after firing.

In this present work, the wood is pulverized and actually mixed into the clay body thus creating an honey comb porous body after firing. However, this project would have been hampered by the current agitation and cry against deforestation. Watch-Tower (2010:18) posited that an area equivalent to 1200 soccer fields (10,800,000)m^2 is logged illegally each day in Amazon forest alone. One needs to imagine the amount of wood that would have been destroyed each day for one use or the other. It would be argued and confirmed that the approach contributes to depleting the ozone layer (Mother Earth News, 2010:2-3). In this work, decayed oil palm wood was utilised as the source for energy extraction and its weight effect. This became justifiable as the research is poised to putting to use wood waste or already cut down and unwanted non productive oil palm (*Elaeis guineensis*) stems.

Recycling in this manner even seems to point to a way of solving the problem of pollution, which appear to be global and needs practical and realistic approach. By this type of research, industries, business and other ventures could solve their problems synergistically, especially in the ceramics world. In an attempt to solve material problem in ceramics, a ceramist commented, 'potters will search for a clay which first of all has the right reaction to the fire and produces a fired substance of desired properties from internal and external factors, (Rhodes 1968:98)'. These properties may be the energy mode, material melt tendencies, acceptable values, technological suitability involving transformation, conservation, preservation, reservation strength and weight. As ceramics involve materials and processes with its complex industrial production nature, energy becomes an inevitable need in its survival. Manipulations of these energy sources to achieve the desired products become challenges.

Grahl (2004:27) revealed that ceramic industry problems have been and are still so enormous that it would need a concerted effort to surmount it. Grahl (2004:27), therefore, encourages industrialists to use human and material resources in meeting our industrial needs. It has been observed that in Akwa Ibom State, and of course Nigeria as a country in West Africa, there are available human and material resources which could be exploited towards the development of the state (Ukpong, 1987:87). This means that modern researchers should now look inwards for solving our problems. The use of Pulverised Oil Palm wood (Elaeis Guineenis) in clay body for firing becomes expedient because of the effects of either the carbon content for heat energy release or inorganic oxides present as fluxes to complement the fusion process(Gladstone1948:184).

In a country where raw materials are not tapped to the fullest, the nation's modern technologists will be held responsible by future generations for not attempting to solve the problem. In order to solve this problem in ceramic industry, the abundantly available clay as ceramic raw material and the pulverised oil palm wood as one of the energy sources for firing the clay body were utilised in producing ceramic wares. The main question in this kind of study therefore would be: will effective use of pulverized oil palm (*Elaeis guineensis*) wood in clay body create advantageous effects on the weight of the wares after firing?

The purpose of this study therefore is to determine the need for the inclusion of organic fuel source, Pulverized Oil Palm Wood (POPW), in clay body and the effects on ceramic firing experiences.

The objective is to determine the effects of the pulverized oil palm wood in clay body on the ceramic weight after firing;

To realize the set objective, the research sought answers to the following question: are there any effects of the pulverized oil palm woods in clay body on weight after ceramic firing?

The following null hypothesis was developed to generate data for the study: there is no significant effect of the pulverized oil palm wood in clay body on weight after firing.

The rationale of this study is hoped that the findings would be useful to: the ceramists in industries; for the updating of materials for production, giving information on weight, which would determine economic viability of the products when compared to the traditional clay body product which does not utilise pulverized wood. The results of this study apart from empowering students with new technologies in ceramics would also contribute to the survival of ailing ceramic industries. The findings of the research would promote lightweight ceramic products and increase the aesthetic quality of the ceramic body. The ash contents of the oil palm wood would be used to substitute most fluxes in ceramics. Therefore, the wasted oil palm wood in our farms would complement sources of fuel in ceramic firing; this means reducing dependence on crude oil products. It is hoped that the findings should increase the enthusiasm of those who dropped out from ceramic undertaking because of high cost of firing and fluxing materials.

As this research is poised to innovate raw materials, the information derived from modern technology is intended to meet national needs and the objectives of the Nigerian Universities Commission (NUC) which include, among other things, to produce high quality graduates with technological capacity to compete favourably in national and international ceramic enterprise. The academic community would also stand to benefit from this work by becoming innovative and developing efficient practical consultancy. Precisely, this work will incubate, empower and support entrepreneurship and create employment opportunities for Nigeria.

The wood used in this study was delimited to the adopted oil palm wood (*Elaeis guineenis*) in Akwa Ibom State. These palm trees were delimited to the traditionally wild local oil palms with diminishing fruit yielding ability only. This was because they are abundant and when their yielding capacity declines they are cut down for replanting new improved species quite unlike the cultivated plantations which are expensively developed and highly valued. .

Clay body: the study was delimited to the adopted clay body (Ebe's recipe) analysed in the Department of Soil Science Laboratory, University of Uyo. (see table 1, 2)

Table 1: Analysis of oil palm wood before experiment (wt %).

Element	Al_2O_3	SiO_2	FeO	Fe2O3	Ca	K	Na	Mg	Sn	Pb	Co	Cr	Mn	C
Quantity	4	15	0.20	0.36	0.01	0.01	0.12	0.05	<0.01	<0.01	<0.01	<0.01	0.20	80.1

Table 2: Analysis of clay body before experiment (wt %).

Element	Al_2O_3	SiO_2	K_2O	Na_2O	CaO	PbO	Fe_2O	MgO	Sn	Co	B	Cr	Mn
Adopted Clay body Quantity	20	76	1.01	1.82	0.04	0.05	0.57	<0.01	<0.01	<0.01	<0.01	<0.01	0.22

The study was delimited to the objective of the effects of the pulverized oil palm wood in clay body on ceramic weight after firing. The effectiveness of the experiments was tested with the result of the fired POPW clay body out come.

The theoretical framework that governed the experimental process was the Phlogiston Theory of Becher of 1667: Phlogiston theory states that combustible resources contain phlogiston, a substance without colour, odour or taste that is liberated in burning. Once burnt, the dephlogisticated substance was held to be in its true form, the Calx, described in a way basically opposite to the real way of the role of air in combustion. However, Lavoisier in 1717, showed that combustion required a gas called oxygen for a new caloric value of combustion thus:

Carbon fuel source: methane(CH_4) and oxygen ($2O_2$) when heated yielded water ($2H_2O$) and carbon iv oxide(CO_2) and energy (Sharma and Sharma 2005:169-183). In summary of the theory, the enduring aspect was that Air supports combustion.

The fact that air is made up of 78% of nitrogen, 20% of oxygen, 2% of carbon dioxide and inert gasses and supports combustion showed that there was enough oxygen in air to support combustion (Sharma and Sharma2005:169-183).

Application: Air with this 20% of oxygen, was applied in the firing process of this experiment, and Pulverised Oil Palm Wood (*Elaeis guineesis*) used as fuel source.

The definitions of ceramic expounded by Rhodes (1968:68), Cardew (1971:146), and Umar in an interview in 2006), and other renowned ceramists as considered in this research, permitted the inclusion of other materials in clay body. Fortunately, clay and clay body qualities have been taken care of through combination of clays and other materials even in traditional pottery.

In a similar study Clark (1968:68), Oke and Udom (2007:54-61), Ekong (2000:93-98) maintained that the incorporation of other materials other than clay would change the face of pottery. Another additive expert Sulton (2011:27), in Active-Mineral, claimed that acti-gel-208 improves ceramic melt and body formulation.

It is stated in the *Ceramic Industry* 2004, that additive (A) does not cost much but it is advantageous because it increases production rates, reduces power consumption and increases green and fired strength.

From the forgoing, there was the need to look inward for local materials to add to clay for its suspected characteristics, like lightness, fluxing action, combustible power, porosity, strength and cost effectiveness.

In the course of experiment, extraction, grinding and milling of the oil palm wood were done to 100 mesh in a ball mill.

In search of suitable clay body for the making of clay brick, a researcher Okongwu (1988:1409-1441) experimented with small additives of 2 – 3% of sawdust of unspecified wood to clay to compose bricks which was fired at 800^{o}C and it was tested. Its results proved that sawdust in low concentration of 2% improves absorption. However, Okongwu (1988:1409-1441) sugested that the optimum sawdust content was a function of length of firing (heat work done). In the present experiment, the milling time was increased so as to reduce particle size of wood. Choice of wood dust was specified: oil palm wood (*elaeis guineenis*) analysed to establish the element contents. The time of firing increased to exhaust each wood energy firing to its maximum temperature. This was recorded as results of internal combustion backed up by only air. In the second phase of firing, as soon as this stage was reached, butane gas was employed to finish firing to maturity at cone 6, (1230^{o}C).

The particle size of wood, according to Arnothe and Litvan (1988:1412-1414) was a factor in the clay body homogeneity. This explained why the work of Cardew in 1968 the big logs of wood gave energy only from external combustion. If the wood were to be made into tiny particles and actually mixed with the clay body, then, there would have been an internal combustion in the green ware. Hence the researcher's axiom: 'wood in clay' and 'not wood on clay'. However, there must be a conditionality regarding the ratio of clay to the additives. An experiment carried out by Zakin (1990:7) indicated that percentages of clay for successful clay bodies were as follows:

1. high clay percentage clay bodies = clay 90% and non-clay material 10%
2. medium clay percentage clay bodies = 60% and non- clay material 40%
3. low clay percentage clay bodies = 50% and non- clay- materials 50%

Zakin's pie chart recommended the correct clay body composition for a successful firing. Therefore the percentage of additives to make an effective clay body was guided by Zakin's work:

Weight of the Ceramic Bodies: The contents of the clay body (ie orgnanic or inorganic) determines the final weight of the ceramic ware and Sulton (2011:22) has gone to a great length in developing ceramic bodies that increase in its strength, temperature, and heat conductivity. Okongwu (1988:1409-1414) experiment of breaking strength in burnt brick of saw dust additives was attempted with loading success.

The particle size, the temperature and the homogeneity can be innovated to rise above brick making. By observing Okongwu's experiment, it is noticed that a temperature, and the unspecified saw dust content allowed gaps that could be filled. This called for temperature increase from 800^{o}C to 1230^{o}C in the present experiment to allow the fluxes in the specified materials to vitrify. Rhodes (1968:101), Hamer (1977:311), and Ojie and Esosuakpor (2008:96-103) agreed that when a ceramic body has undergone closure of some of its pores, vitrified and shrunk, changes in volume, weight and density may occur.

Material Preparation: The oil palm wood stem of 20 kg collected was ground in ordinary grinder then ball-milled wet for 12 hours to pass through 100 Bs mesh sieve. The ball-milled POPW was mixed with slaked clay as indicated in the composition. This was to ensure a homogeneous mixture with the clay body itself. The composition achieved was allowed as paste to stand for two weeks for ageing so as to increase plasticity.

The composition: The adopted oil palm wood formed the specimen that was added to the controlled clay body (Ebes), in the proportion of 10%, 20%, 30%, 40% and 50%. To have enough of each representation of these batches for at least ten (10) pieces, it became necessary to take the following steps:

i. To prepare 10% oil palm stem wood to 90% clay body, 10%: 200gms of ground oil palm wood samples was added to 90%, that is, 1,800 grams clay body to form a total of 2kg (2000 grams) of specimen 1. Specimen was mixed in enough water to form slurry, allowing overnight for fermentation. It was ball-milled for twelve hours, sieved through 100 mesh. The slurry was dried to paste state ready for use.

ii. The process was repeated to specimen 2, that was, 20% (400g) oil palm sample with 80% (1,600g) clay body to form a total of 2kg (2000g).

iii. The process was repeated to specimen 3, that was, 30% (600g) oil palm sample with 70% (1,400g) clay body, totaling 2kg (2000g).

iv. The process was repeated to specimen 4, that was, 40% (800g) oil palm sample with 60% (1,200g) clay body, totaling 2kg (2000g).

v. The process was repeated to specimen 5, that was, 50% (1000g) oil palm sample with 50% (1,000g) clay body, totaling 2kg (2000g). The figures were recorded in table 4.1.

Design and Production: The size of the dice needed for the experiment was (12 x 4 x 1.5) cm^3. This was to ensure suitability for the experiment. It was produced by pressing method of one bar of pressure in metal mould at a bread dough paste state. Similar method of production was applied to the entire specimens which were identified and kept for one week to air dry for firing. In drying out it was necessary to keep them flat between moderate load of paper to ensure flattened surface.

Loading and Firing: Enough amount of each percentage level (10 – 50)% wt progression of pulverized oil palm wood was loaded for each batch of firing. The pyrometric Orton cone levels, 022 to 6, for firing maturity reliability, were laid together with the specimens in the kiln. Hamer's specification in the table of incandescence also applied to check the kiln interior glow confirmed a thermocouple (Hamer, 1977:344) at the end of exhaustible combustion temperature of each specimen, the group temperatures were recorded and the firing stopped. These were based on 650^{o}C, 700^{o}C, 800^{o}C, 900^{o}C and 1050 while the limit for liquefied gas group was 1230^{o}C maximum temperature. Having recorded the data that would help test for different effects as required in the objectives, the researcher shut off the kiln and allowed it to cool to room temperature before unloading finally. This was for kiln safety.

The experiment: determination of the weight of the Ceramic tile after firing.

Experiments were conducted in stages 1, 2 and 3.

Stage 1 was made up of the control specimen of 100% Ebe's clay body(adopted clay body) and 0% POPW fired traditionally with gas to cone 6 (1230^{o}C).

Stage 2 was made up of the determined percentage composition of Ebe's clay body and POPW specimens fired with air only to exhaustible energy level.

Stage 3 was made up of the stage 2 augmented with gas to cone 6 (1230^{o}C).

Experiment 1 Stage 1 Specimen: Control: 100% Ebe's clay body without POPW was fired traditionally with gas to cone 6 equivalent of 1230^{o}C and cooled to ambient temperature. Three readings were taken and the average calculated. The results are registered in Table 3. Specimen measurement (weight)

93.21gms

93.20gms

93.22gms

Mean 93.21gms

Experiment 1 Stage 2 Specimen 1: 90% Ebe's clay body blended with 10% POPW was fired with air only to exhaustible heat energy level and cooled to ambient temperature. Three readings of weight measurement were taken, the average calculated recorded in Table 3.

Experiment 1 Stage 2 Specimen 1 procedures were repeated for specimens 2, 3, 4 and 5, to their exhaustible heat energy levels. They were cooled to ambient temperature and measurements taken. Three readings for each specimen were made and the average calculated recorded respectively in Table 3.

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Experiment 1 stage 2 of specimen 1 was repeated for stage 3. At the exhaustible heat energy level, it was augmented with gas to cone 6 equivalent to1230°C, cooled to ambient temperature, and measurements taken. The average reading was calculated and recorded in Table 3.

Experiment 1 Stage 3 Specimen 1 was repeated for specimen 2, 3, 4 and 5. Gas was augmented at exhaustible heat energy levels to cone 6 equivalent 1230°C, cooled to ambient temperature; an average of three readings was calculated and recorded in Table 3 for each specimen respectively.

The purpose of this research was to determine the effects of (10 – 50)% weight of pulverized oil palm *Elaeis guineensis* wood (POPW) in clay body and weight after ceramic firing. Experiments were conducted, data obtained and the analysis done, using mean standard deviation for research questions and independent t-test for the hypothesis as shown in table 3.

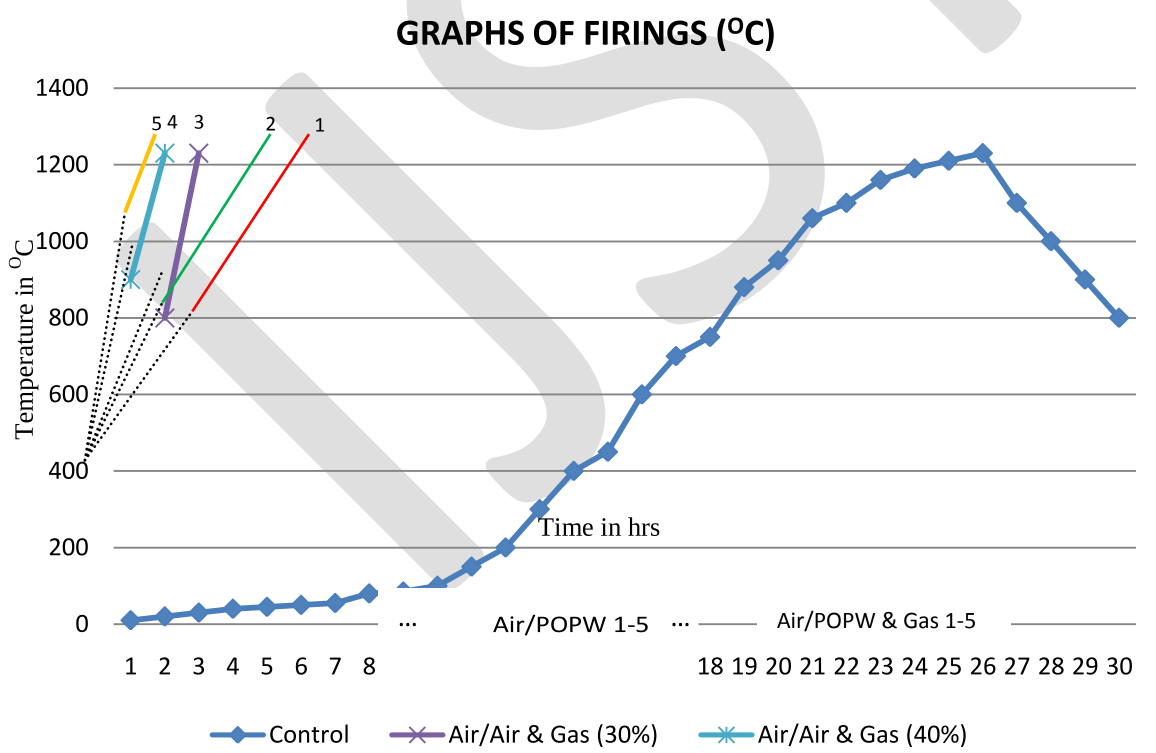

Table 3: The Effects of pulverised oil palm wood (POPW) in clay body on weight after ceramic firing.

Specimen	**Clay Body in %**		**Weight of Piece in Firing with Air only**	**Weight of Piece in Firing with Air and Gas to cone 6**	**Weight of Piece in Firing with Gas only to δ6**
	Ebe's clay body	POPW	In gms	In gms	In gms
Control	100	0	-	-	86.32
1	90	10	93.21	78.25	
2	80	20	84.43	61.63	
3	70	30	63.53	46.62	
4	60	40	52.22	45.76	
5	50	50	47.24	44.64	
Calculated mean:		x =	68.126 :	55.380	
Standard deviation:		std =	20.034 :	14.549	

NOTE: Each reading was the average of three observations

Entries in Table 3 show less mean of 55.380 gms and greater mean of 68.130 gms for clay body when fired with air and liquefied gas, and with air only respectively. The standard deviations of 6.507 and 9.959 gms show the variability of each score from the mean.

The result implies that clay body weight is less when fired with air and liquefied gas, than with air only. This result is further demonstrated in Figure 15.

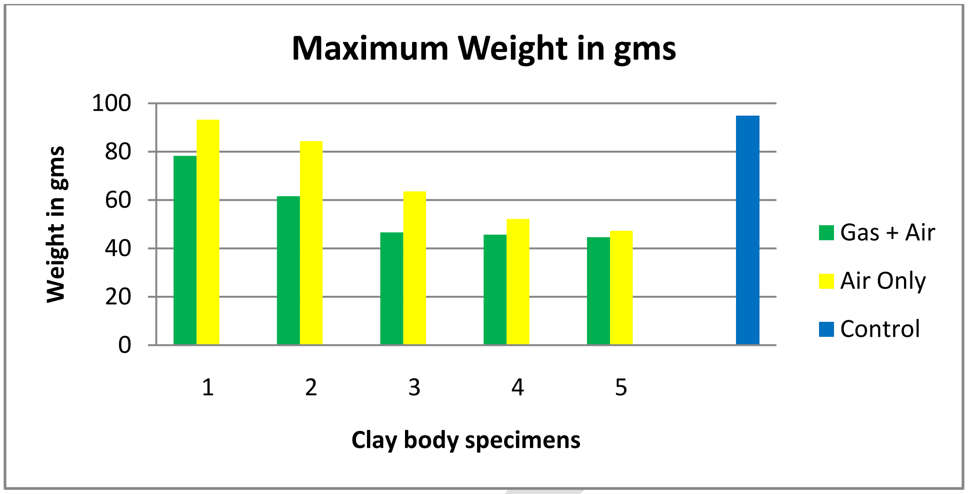

Figure 2 : Maximum Weight in gms of Ebe's clay Body and POPW compositions, 1 to 5 in ceramic firing

The research question here is: are there any significant effects of pulverized oil palm wood (POPW) in clay body on weight in ceramic firing?

The graphic presentation revealed that the estimated marginal mean weight for the two types decreases across the composition levels, but decreases further when firing with liquefied gas and air than with air only.

The hypothesis**:** there is no significant effect of pulverized oil palm wood (POPW) in clay body on ceramic weight after firing.

Table 4: Summary of t-test for the effects of POPW in clay body on weight in ceramic firing.

Variable	Firing	N	Mean	Std deviation	df	t-cal	t-crit
Weight	With Air only	5	68.13	20.034		1.151	
					8		2.309
	With Air and liquefied gas	5	55.38	14.549			

** Significant at 0.05 level of significance*

Table 4 showed that the calculated t-value of 1.151 was greater than the critical t-value of 2.309 at .05 level of significant with 8 degrees of freedom. The result is significant; therefore, the hypothesis that there are no significant effects of the POPW in clay body on weight in ceramic firing is rejected. The result means that POPW affects clay body weight in ceramic firing.

Table 4 showed that the calculated t-value of -2.971 was greater than the critical t-value of 2.309 at .05 level of significance with 8 degrees of freedom. The result is significant; therefore, the hypothesis that there are no significant effects of POPW in clay body weight on ceramic firing is rejected. Therefore POPW in clay body affects weight in ceramic firing.

Findings and Discussion: Findings in Table 3 and 4, Fig 1 and 2 show that increment of POPW and temperature reduced the weight of the fired piece significantly. POPW at a mean weight of 820^{o}C has a mean weight of 68.3gm weight whereas POPW at a mean temperature of 1228^{o}C has a mean weight of 55.38 gm weight. It is noted that, 100% Ebe's clay body composition (control), the weight is 86.32gms. The difference of 18.29gm wt and 30.96 gm wt of POPW at high temperature show that there is a great loss in weight at all levels. These confirmed that the ceramic products lost weight when compared to its green ware stage. This is because some hydrated water, the volatile materials, organic matter, and some gases liberated during firing. In the case of this experiment, the hydrated water and gas were common to both the control and the POPW clay body; but the POPW in clay body was plagued with more of organic substances and gases which were bound to be liberated during firing. The utilisation of Lavoisier's theory of adding oxygen as agent of combustion should have actually increased the weight because of the oxidation that has occurred; but the amount of matter that had been sent out (organic and volatile materials) was more comparatively as some of the oxygen was also liberated as a component of carbon (iv) oxide (CO_2). Although the metallic oxides left behind after combustion have added some weight to the finished piece, this could not make up sufficient weight to offset the weight loss. Reduction in weight therefore is a significant effect in the experiment and the result enables light weight materials to be produced with the POPW in clay body products.

In conclusion, the research has taken into consideration the objective, and the null hypotheses formulated to guide this study were rejected. Also considered were the findings related to the problems the research had posed, that is, finding a way of solving weight problems by utilizing the neglected raw materials like the wood of felled oil palm trees in ceramic firings in Nigeria. It has considered the way of adapting the firing process in a convenient modern method. In consideration of the outcome of combination of wood and gas augmentation, the acceptability of the effects on the society's utilising efficiency, the contribution it will have on ceramic profession, above all, the possibility of not only creating job but retaining the establishment that creates the jobs for sustenance. This is expected as the results of findings in heat conservation, weight reduction has been unfolded in the research. The control of the weight and volume of the ceramic piece; and above all the reduction of the cost of fuel consumption in ceramic firing is interesting. This work has introduced a new cheaper method of firing ceramic wares by utilizing energy source (wood) directly in clay to formulate wood-in-clay green wares before firing with gas as against the usual firing by wood-on- clay method or gas alone. The paper is poised to conclude that the research points a way to a better future for the Ceramics Industry in utilizing weight reduction strategies.

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